Application of quantal hypernetted-chain approximation to hot dense plasmas

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I. INTRODUCTION

It is natural to think of a liquid metal or a plasma as composed of ions and electrons. The quantal hyper-netted chain approximation (QHNC) has been applied to liquid metals. Their results are in good agreement with experiments [1]. In this paper, I calculate the stopping number of charged particles in the plasmas characterized by the ion number density n_i of approximately 10^{23} cm^{-3} and the plasma temperature k_BT roughly 50eV. 1eV is approximately equal to 10000 degree. I will try to apply QHNC to such plasmas.

First, in order to investigate the quantum diffraction effect on such hot dense partially degenerate plasmas, I compare the stopping numbers obtained by QHNC jellium model with those obtained by HNC jellium model. Second, to investigate the discrete ion effect on the stopping number, I calculate the stopping number of charged particles by using full correlation atomic model (FCAM) [2].

Note that in this work, the free electron distribution function around a free electron is obtained by solving Schrödinger equation.

II. RESULTS AND DISCUSSIONS

The stopping number of charged particles is written as Eq. (5.6) in ref. 2. In the electron jellium approximation, the dielectric function $\varepsilon(k,\mathbf{kv})$ is written as follows:

$$\frac{1}{\varepsilon(k,k\cdot v)}=1+\frac{4\pi/k^2\chi^{(0)}(k,k\cdot v)}{1+\chi^{(0)}(k,k\cdot v)\,\hat{c}_{e-e}(k)\,k_BT} \tag{1}$$

Where $\hat{c}_{e-e}(k)$ is the electron-electron direct correlation function and can be obtained by QHNC jellium model or HNC jellium model. The strong-coupling effects beyond the RPA are included in $\hat{c}_{e-e}(k)$.

I estimate the rate of the stopping number obtained by QHNC jellium model to that obtained by HNC jellium model for three cases. First case is $\Gamma=1$, $\theta=1$ ($r_s=1.8416$, $n=2.58\times10^{23}cm^{-3}$, $k_BT=14.78eV$), second case is $\Gamma=0.5$, $\theta=1$ ($r_s=0.9208$, $n=2.06\times10^{24}cm^{-3}$, $k_BT=59.10eV$), and third case is $\Gamma=0.5$, $\theta=0.5$ ($r_s=0.4604$, $n=1.65\times10^{25}cm^{-3}$, $k_BT=118.20eV$). In Fig. 1, the results of described above are shown. As shown Fig. 1, the quantum diffraction effects in QHNC on the stopping number increace as the r_s decreaces.

In order to estimate the electron-ion strong-coupling effect on the stopping number, I calculate the electron-ion direct correlation function by using FCAM. The stopping number in two-component strongly-coupled plasmas is obtained by Eqs. (5.6)-(5.9) in ref. 2. In Fig. 2, the electron-ion strong-coupling effect on the stopping number for the first case is shown. The solid line represents the ratio of the stopping number without the electron-ion strong-coupling effect to that with the electron-ion strong-coupling effect. The dashed line represents the rate of the stopping number obtained by QHNC jellium model to that obtained by HNC jellium model. As shown in Fig. 2, the solid line greatly oscillates at the range of $v\sim0.15v_{Te}\sim0.4v_{Te}$. For the first case, roughly speaking, the electron-ion strong-coupling effect is comparable to the quantum diffraction effects in QHNC because of the values of r_s and θ.

References

1). J. Chihara, Prog. Theor. Phys. **72**, 940 (1984) and therein.

2). H. Furukawa and K. Nishihara : Phys. Rev. A **46** (1992) 6596.

Fig. 1

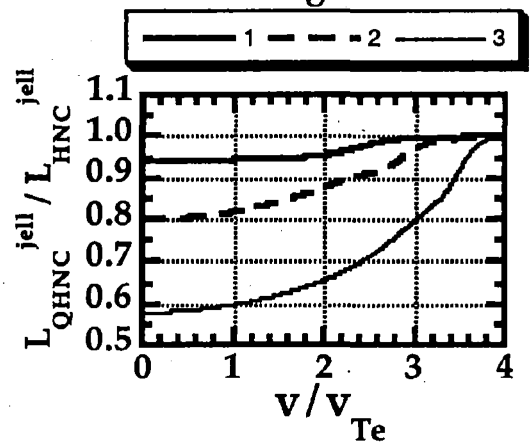

Fig. 2